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# Smart Institutions for Smart Cities

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**Abstract.** Smart cities employ creativity of the population for innovations supporting social and economic development. In this context, this paper explores the role of framework conditions on special supply effects of university hospitals, which can invite further research institutions for intense collaboration, thereby stimulating innovations. The case study, comparing a hospital in Russia with one in Germany, is based on the concept of the employment multiplier. The results show that exogenously given, but, more importantly, also modifiable framework conditions lead to large differences regarding the employment multiplier. Thus, it should be the concern of smart cities to make smart use of their institutions, such as university hospitals, by adjusting the conditions, under which they are operating.

**Keywords:** smart city, smart institution, university hospital, economic impact, supply effect.

## 1. Introduction

Smart cities are making use of knowledge and creativity to stimulate innovations, which help to better respond to the social and economic needs of the people [1–3]. In addition to information technologies, appropriate framework conditions are required to support the development of smart cities, for example, through optimal use of institutions, which are present in large cities anyway. In this context, this paper refers to university hospitals with their wealth of disciplines possibly attracting and inviting other research institutions and spin-offs for collaboration. Clearly, nature and extent of this collaboration depend on a variety of framework conditions, some of them given exogenously, some of them, however, determined by factors, which could, at least in principle, be modified and adjusted.

Thus, relevant research questions are: how to measure and how to increase the economic impact of these research hospitals by means of suitable framework conditions? For a first approach a university hospital in Germany (University Medicine Leipzig: UML) is compared to a university hospital in Russia (Siberian State Medical University Tomsk: SSMU). Since the early 1990s there have been various reforms to the Russian health care system with significant changes in the framework conditions [4, 5]. Similar to the German health care system [6, 7], the performance of the Russian system has been monitored over the last decades [8, 9], pointing to deficiencies and providing recommendations for further changes to increase efficiency [10, 11]. Thus, a thorough comparative



economic appraisal of renowned university hospitals in Germany and Russia should allow some interesting conclusions.

The analysis of economic effects of universities and institutions of higher education has been addressed in the literature. Research on the regional economic impact of universities concentrates thereby mainly on the generation of income and employment through the universities' and their students' expenditure within a region [12–15]. Various studies estimated the economic impact of universities either by using the Keynesian multiplier model or by means of sector-specific input-output analysis [12, 13].

Less attention has so far been given to the role of an academic institution as a generator of scientific output, an academic institution teaches and trains students, and delivers executive education. In addition to the provision of human capital through well-educated graduates, research results, patents and spin-offs stimulate and accelerate innovation activities, which are of importance for further regional economic growth. There is, in particular, a need for appropriate measures, and for cross-national comparisons regarding these effects [15, 16].

Given this situation, this paper focuses on a more detailed analysis of special supply effects, associated with the two university hospitals located in different countries. The analysis allows some conclusions regarding the relevant framework conditions, also those, which can be modified. The ultimate purpose of this investigation is, thus, to provide some ideas on the concept of a smart institution, or a smart infrastructure, of relevance for a smart city [1–3].

## **2. Conceptual Framework**

### *2.1. The economic impact of university hospitals*

Apart from their role as providers of health care and higher education, university hospitals have been predominantly considered as expense factors, in particular from the point of view of the public administrations. The primary focus of these impact models [12–14] is the calculation of direct effects (income, consumption and employment effects, which are directly related to the university), indirect effects (generated by expenses of the institution with respect to construction and materials; third-party funded positions, effects of research institutes, effects caused by students and visitors) and induced effects ("induced" by the consumer spending of all employees). The ratio of direct effects to the sum of all effects can be interpreted as multiplier.

This focus is too narrow and neglects diverse economic and spillover effects, which are, admittedly, occasionally difficult to measure. Additional impacts to the benefit of a region include the education and training of a qualified labor force and, in particular, the provision of knowledge, supporting regional innovation activities and spin-offs. The main findings in the literature on the economic impact of universities always point to a significant supply effect of the research efforts on commercial innovative activities [15–18]. The geographical dimension of these knowledge spillovers seems to be limited, and the framework conditions have to be in favor of the transfer of scientific knowledge into the private sector of the economy. Moreover, the type of university (e.g., a focus on technology or medicine) as well as the characteristics of a region decisively affect the intensity of the interaction of universities within the regional economy [16, 19].

The attractiveness of a university hospital for such collaborations as given by the number of employees in external research institutions and spin-offs will be used as a measure for the effectiveness of the relevant framework conditions stimulating innovations. This is the main contribution of this paper to the existing literature, thereby extending and detailing the results obtained earlier [15–18].

### *2.2. Characteristics of UML*

The impact model focuses on UML in 2009, which comprises the Faculty of Medicine (i.e. the Medical School) of the Leipzig University as well as the Teaching Hospital. The Faculty of Medicine

of the University of Leipzig was founded in 1415, shortly after the university was established in 1409. The University of Leipzig is one of the oldest universities in Europe.

Today, the 5,177 staff members of the Faculty of Medicine and the university hospital, as well as the material and construction expenditures constitute the basis for the calculation of the different effects. The 3,129 students of human and dental medicine represent another mainstay of the model.

Some research centers settled in Leipzig because of the existence of the university hospital, and additional spin-offs were established. The 780 staff members of these institutions, comprising among others two Max Planck Institutes and one Fraunhofer Institute, are equally included in the analysis. Further indirect effects result from spin-offs and outsourced institutions that are directly related to the university hospital, such as the Cardiac Center Leipzig, which was established in 1994.

Moreover, visitors of medical congresses and fairs are considered in the calculation of the effects. Medical fairs are held in Leipzig primarily because of its reputation as a medical city with rich tradition shaped by the university hospital and the various non-university research centers.

Further institutions providing offers for students – e.g. libraries or student services – are, however, not included in the analysis even though they are being used by the 3,129 students of medicine. Given that the students of medicine constitute only 8.7 % of the total number of students, this effect has been neglected, as – in contrast to an evaluation of the whole university – the study focuses on the effect of the medical school and teaching hospital.

The region under study is the Free State of Saxony, one of Germany's sixteen federal states with around 4.2 million inhabitants and a size of some 18 thousand square kilometers. All employment and income effects investigated in this study are calculated for the Free State of Saxony.

### *2.3. Characteristics of SSMU*

Each Russian region has a general hospital for adults (500–1000 beds) and a general hospital for children (300–600 beds) that accept referrals of complex cases from district hospitals and polyclinics, as they are intended to provide services for the entire population of the region. All specialties and subspecialties are represented, and the qualifications of staff and the care offered are more sophisticated than at the municipal level. The regional hospital often serves as the teaching unit of the local medical school.

Beyond that there are the medical institutions of higher education in the regions of the Russian Federation. One of them is SSMU in Tomsk, serving the region of Tomsk with a population of a little more than one million inhabitants and a size of almost 317 thousand square kilometers.

Today, SSMU is one of the leading medical universities in Russia. Its history dates back to 1878, when the Emperor Alexander II founded the first university in the Asian part of Russia. Imperial Tomsk University opened in 1888 with only one faculty – the Faculty of Medicine. Interestingly, the university was originally established to function as a research and educational center.

SSMU hosts various research centers focusing on molecular medicine, bioengineering, laser technology and others (cf. [http://www.international.ssmu.ru/ru/research\\_innovation/research\\_centers/](http://www.international.ssmu.ru/ru/research_innovation/research_centers/)). The research centers promote the application of modern methods to conduct clinical and academic research and aim at creating an integrated system of research and innovation with the help of international scientists.

The basis for calculating the various economic effects is provided by the 2,369 staff members, and the 2,564 students of human and dental medicine.

## **3. Methodology and Data**

The analysis is based on a case study approach with data from UKL and SSMU. The data were collected in close collaboration with the management of the hospitals.

We adopt in this paper – following the multiplier approach – a special impact model, an incidence analysis, which observes the flows of expenditures and their distributing impacts and helps to determine direct income, consumption and employment effects. The model will be likewise applied to study the demand side effects of UML in Germany and SSMU in Russia, with a special view on the

supply side issues mentioned above. In the model, the respective institution is considered a consumer of various inputs. These inputs consist of the expenses for construction, material, personnel, etc. within one year. The goal is then the analysis of the regional economic impact of these expenses. These calculated demand effects can be divided into direct, indirect and induced effects. Although there are no consistent definitions in the literature, direct effects refer to primary income, consumption and employment effects originating from the analysed institution. Indirect effects arise from the university's material and construction expenditures. Moreover, the term comprises effects of third-party funds, outsourced establishments, research centers and spin-offs as well as students and visitors of medical fairs. Induced effects, for example in form of increasing employment, result from the staff's consumption expenditures and the related demand of goods and services. Income effects describe direct, indirect and induced incomes resulting from the existence of the analysed institution. Consumption effects describe the staff's consumption expenditures separated into different sectors.

This analysis focuses mainly on employment effects that are composed of direct employees (university hospital staff), indirect employees (university hospital staff paid by third-party funds, staff in supply firms as well as staff in research centers and spin-offs) and induced employees, the latter being employed because of the staff's consumption expenditures. Special attention will be given to the supply effects associated with external collaboration.

#### **4. Results of the Impact Analysis**

The analysis is based on the calculation of direct and indirect employment, income and consumption effects and the induced effects, which have to be broken down to the area of study (Free State of Saxony resp. the Region of Tomsk). Indirect employment effects arise from third-party funded projects and from other research institutions, which settled in the area because of the existence of the university medicine.

Again, in order to calculate direct income effects for the employees of the hospitals, internal staff statistics are used. A similar procedure is applied regarding the indirect income effects from employees of the research institutions and from the third-party funded projects. For the estimation of direct and indirect consumption effects of employees, students, and visitors of the fairs recourse is made to special surveys [20].

The induced effects are basically calculated by means of a multiplier analysis: a complex multiplier is used in order to ensure the consideration of separate sectors. This requires the determination of a regional consumption rate since the induced employment and income effects consider only the proportion of consumption expenditures that take effect in the region under study.

##### *4.1. Results for UML*

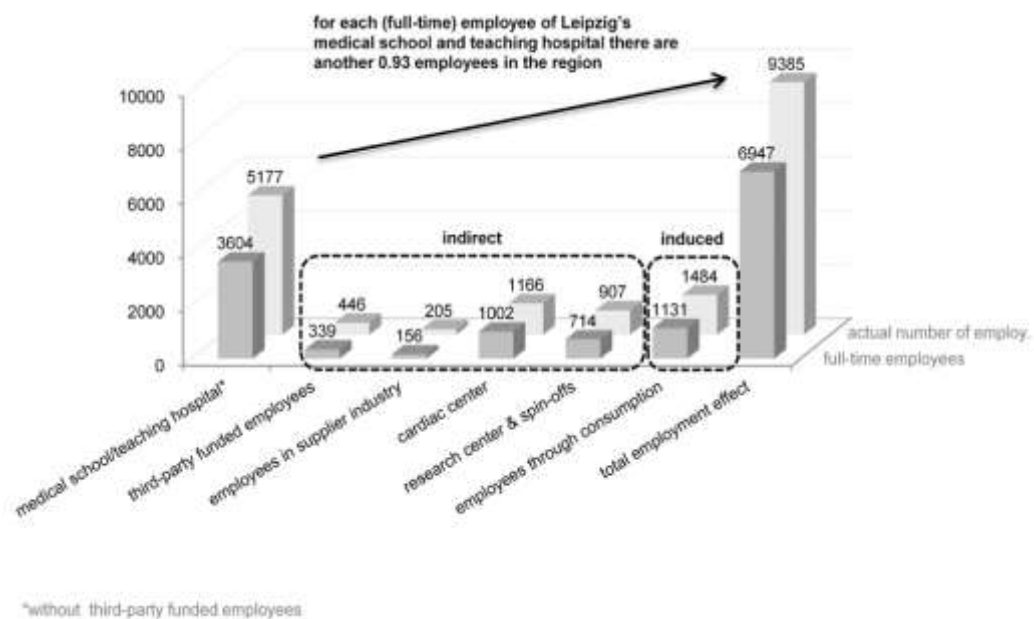
In 2009 there were 3,604 full time employees at both the medical school and teaching hospital of Leipzig. Another 339 full-time employees were paid by third-party funds. During the period of study 714 full-time employees were listed in the associated research centers and spin-offs, as well as 1,002 in the Cardiac Center. Additionally, the analyzed institution created and maintained jobs in Saxon supply firms due to its material and construction expenditures and expenditures for qualifying measures. 156 employees were identified by means of the method described above. Altogether the analyzed institution ensures directly and indirectly 5,817 employees.

The direct income effects, thus the employees' gross incomes (excluding third-party funded employees) amount to 158,097,524 € per year. Employees paid by third-party funds had indirect income effects of 15,493,400 €. Regarding the employees of the Cardiac Center the income effect was determined to 48,956,432 €, for associated research centers and spin-offs it amounted 22,868,051 € and 4,327,497 € for the suppliers' employees.

The consumption expenditures of the employees of the medical school and teaching hospital, the associated research centers, spin-offs and supply firms as well as the students and visitors of medical fairs amounted to 198,292,193 € per year. 25.5 % of this sum was spent on housing, housing maintenance and energy, 13.6 % on foodstuffs, drinks, tobacco products and 17.3 % on transportation.

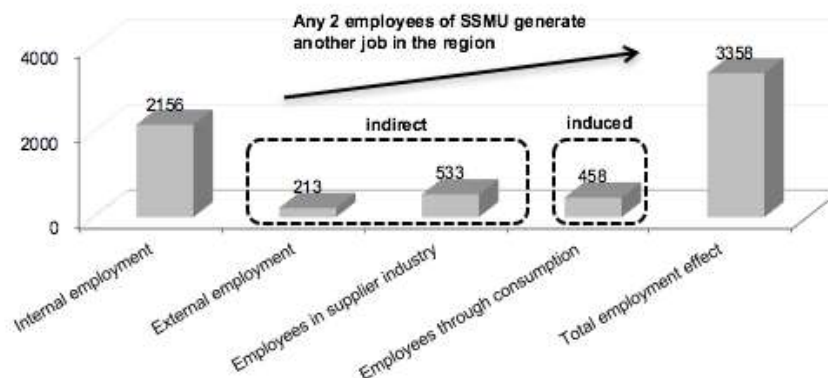
Due to the re-spending of a part of the consumption expenditures in Saxony, another 1,131 jobs were created in enterprises in different economic sectors. These employees received a gross income of 32,958,895 €, of which 23,663,788 € were spent on consumption. The indirect process can be repeated seven times until no further consumption expenditures and thus employments are induced. However, 89 % of the effects are already realized after the first run.

6,947 direct, indirect and induced full-time employees were financed due to the analyzed institution in Saxony in 2009. This corresponds to an employment multiplier of 1.93 implying that each (full-time) employee of Leipzig's medical school and teaching hospital supports another 0.93 employees in the region. The actual number of employees (in the sense of created jobs) is higher than the calculated number of full-time jobs: the number of direct, indirect and induced employees is 9,385. This corresponds to an employment multiplier of 1.81 (Figure 1).



**Figure 1.** Employment multiplier and further results of the case study for UML

The gross income multiplier is calculated to 1.49. The difference between the employment and the income multiplier can be ascribed to the more detailed contemplation of earnings-related consumption expenditures and special sectors.



**Figure 2.** Employment multiplier and further results of the case study for SSMU



#### *4.2. Results for SSMU*

In 2014 there were 2,155.8 internal full-time employees and were 2,564 medical students at SSMU. Moreover, 212.5 were listed as external employees and expenses of the Medical University (483.5 million Ruble for material and another 47.3 million for investments) led to 304 employees in supplier industry. In total 516.5 indirect employees are found in the study. The number of induced employees amounts to another 458. Altogether the analyzed institution ensures directly and indirectly 3,358 employees. This amounts to an employment multiplier of 1.56, which is detailed in Figure 2.

The direct income effects, thus the employees' gross incomes (of the 2,155.8 internal employees) amount to 623.0 million Ruble per year. Due to additional gross income of external employees, employees in the supplier industry and student incomes, the analysis yields then an income multiplier of 1.74. Figure 2 shows the various components of the direct and indirect income effects for SSMU.

#### *4.3. Comparison of the results*

The analysis reveals employment multipliers of 1.93 for UML and 1.56 for SSMU, and income multipliers of 1.49 for UML and 1.74 for SSMU. The attractiveness of the university hospitals for external research institutions and spin-offs deserves, however, special attention: For UML, the cardiac center, research centers and spin-offs account for an additional 1,716 full-time positions. Adding the corresponding induced effects of 365 positions associated with these employees, one obtains 2,081 positions resulting from the scientific attractiveness of UML. This leads to a scientific employment multiplier, characterizing the effectiveness of the institution in view of the requirements of a smart city of 1.58 for UML. For SSMU, the corresponding numbers show 213 external employees, inducing additional 41 positions with a total of 254 employees generated through the scientific attractiveness of SSMU. Thus, the scientific employment multiplier for SSMU is 1.12.

The differences result obviously from differences in the relevant framework conditions. Some of the relevant framework conditions are, of course, exogenous in nature. One has to mention the density of the population, the size of the region under study, but also the differences regarding gross regional product (GRP) per capita. GRP per capita is a measure of regional income, which has an effect on demand for medical services, but also for innovations [21].

However, the higher scientific employment multiplier for UML likely results also from factors, which are related to organizational issues, maybe cultural issues. There is, in particular, the aspect of openness of the scientific environment. How easy is it, for external companies or spin-offs to cooperate with a large public-funded research institution? How easy is it, to setup a spin-off in the vicinity of such an institution? These are some of the questions, which result from this cross-nation study of university hospitals.

### **5. Conclusions**

The results of this cross-national case study reveal substantial differences regarding the economic impact of the university hospitals under study. In particular, the scientific employment multipliers, pointing to the level of efficiency of the institutions with respect to collaboration with external companies, shows significant variability.

These differences result from the relevant framework conditions. Some of these conditions, such as demographics and density of population, are given exogenously, some, such as a general openness towards this collaboration, could be gradually further developed and modified. However, a closer investigation of the specific framework conditions and their specific relevance for university hospitals in Russia and in Germany is required for further research.

The results obtained in the paper are important for making optimal use of the knowledge and creativity of research institutions for stimulating innovations, which help to better respond to the needs of the people living in the cities: smart institutions for smart cities.

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